High-Resolution Shallow Seismic Refraction Tomography Requirements Specification

1. Introduction

The system to be developed combines ROV-mounted transmission of chirp acoustic signals with a roughly 1-6 kHz sweep combined with an array of high-frequency ocean bottom hydrophone (OBH) receivers deployed from the ROV. By having closely spaced receivers and a highly repeatable source, refracted arrival times will be picked to produce a model of the shallow seismic velocity structure using 2D or 3D tomographic inversion.

The target experimental scale will range from subsurface sections 100m across and 20m deep to 1 km across and 200m deep. Given the ~3 kHz center frequency and a sub-meter shot spacing, the best achievable resolution of subsurface structure wshould be about 1m, though this will be limited by the actual receiver spacing used.

The system will be readily exportable to other oceanographic institutions operating ROVs.

1.1. Problem Statement

Since the major system components are COTS units with specified performance that seem to meet the requirements, the major design issue lies in the precise timing needed to support picking multiple refracted arrival times, and ensuring that those times are recorded precisely enough to make sense of the data collected.

Short description of timing budget, 3 parts per billion, etc.

1.2. System Personnel

a) Dave Caress – domain expert and project manager
b) Rich Henthorn – lead engineer and software engineer
c) Mark Chaffey – system engineer and electrical engineer
d) Paul McGill – electrical engineer and OBH consultant
e) Bill Kirkwood – mechanical engineer

1.3. Operational Setting

The operational setting is the environment in which the system is to be used.

1.4. Impact Analysis

Conventional marine seismic refraction methods use low frequency (1-100 Hz) shallow towed sources (e.g., airguns) and widely spaced seafloor receivers (e.g., ocean bottom seismometers (OBSs)) to image crustal-scale structure at resolutions no better than hundreds of meters. Images of subsurface structure at resolutions on the order of a few meters require closely spaced, near-seafloor sources and receivers using high-frequency signals (~3kHz). A capability to image fine-scale subsurface structure will augment ongoing MBARI research on hydrate deposits by Brewer and Paull. Methane and the other hydrocarbon gases trapped in hydrates are climate-impacting greenhouse gases as well as potential energy sources. Therefore, research regarding the formation, stability, volume, and structure of these globally common deposits has considerable societal relevance. High-resolution subsurface imaging will impact important marine geological topics such as submarine faults, hydrothermal venting, and submarine volcanism (e.g., near-axial evolution of oceanic layer 2A).

2. Functional Requirements

2.1. Repeatable Chirp Acoustic source

2.1.1. The system shall be designed for integration with the ROV Ventana in such a way that does not preclude use on ROVs from other institutions (e.g., Ricketts, ROPOS, Jason).

2.1.2. The source system shall be designed for use at a depth of 3000m. Other things being roughly equal, a 6000m rating should be pursued when possible. Year 1 experiment requirement: 300m .

2.1.3. The acoustic source chirp shall have a frequency range of at least 1-6 kHz.

2.1.4. The signal source wavelet driving the acoustic source shall be user-defined, repeatable, and calibrated using a signal editing subsystem. Users shall be able to change the source wavelet during an experiment.

2.1.5. Acoustic pulses shall have a maximum duration of at least 100 milliseconds.

2.1.7 The minimum acoustic pulse interval shall be 1 second.

2.2. Ocean Bottom Hydrophone Acoustic Receiver

2.2.1. The acoustic receiver packages shall be designed for deployment by ROV.

2.2.2. The receivers shall be designed for use at a depth of 3000m. Other things being roughly equal, a 6000m rating should be pursued when possible.

2.2.3. The receivers shall be capable of recording the full bandwidth the source wavelet.

2.2.4. The recording frequency shall be at least double that of the highest source frequency.

2.2.5. The receivers shall record continuously for at least 10 hours. Other things being equal, a 24 hour recording capability is desired.

2.2.6. The receivers shall be able to synchronize internal time with the acoustic source controller as often as necessary during an experiment.

2.3. Source and Receiver Interaction

2.3.1. The accuracy of the travel time shall be within the uncertainty of arrival picks in the time series.

Discussion: Travel time is the difference between the source timestamp as measured from the source and the arrival times in the receiver. Klauder wavelet analysis of 1-6 kHz sweep shows a 0.5 millisecond width. Therefore, the *finest* useful travel time accuracy is +/- 0.25 milliseconds. The acceptable deviation from this measure is uncertain at this point.

2.3.2.